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# LEGUMINOUS CROPS FOR GREEN MANURING.

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## LETTER OF TRANSMITTAL.

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U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF PLANT INDUSTRY,  
OFFICE OF THE CHIEF,  
*Washington, D. C., January 16, 1907.*

SIR: I have the honor to transmit and to recommend for publication as a Farmers' Bulletin the accompanying paper on "Leguminous Crops for Green Manuring," prepared by Prof. Charles V. Piper, Agrostologist in Charge of Forage Crop Investigations.

Respectfully,

B. T. GALLOWAY,  
*Chief of Bureau.*

HON. JAMES WILSON,  
*Secretary of Agriculture.*

## CONTENTS.

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	Page.
Green manuring.....	5
The use of green manures .....	6
The principal leguminous crops.....	7
How legumes get nitrogen from the air.....	8
Inoculation.....	9
Sources of soil nitrogen.....	10
Loss of soil nitrogen.....	11
Composition of green-manure crops.....	11
Green manuring compared with feeding.....	12
Orchard cover crops.....	13
Crops to follow green manures.....	14
The choice of a green-manure crop.....	14
The principal green-manure crops.....	15
Red clover.....	15
Cowpeas.....	17
Soy beans.....	19
Velvet beans.....	21
Crimson clover.....	22
Sweet clover.....	24
Canada peas.....	24
Vetches.....	26
Tangier peas.....	27

## ILLUSTRATIONS.

---

	Page.
FIG. 1. Field of cowpeas ready to plow under.....	5
2. Plowing under a crop of cowpeas.....	6
3. Red clover .....	15
4. Roots of red clover, showing nodules.....	16
5. Cowpea.....	17
6. Soy bean .....	19
7. Roots of soy bean, showing nodules.....	20
8. Velvet bean .....	21
9. Crimson clover.....	22
10. Sweet clover.....	24
11. Canada pea .....	25
12. Hairy vetch .....	26
13. Tangier pea.....	27
14. Roots of Tangier pea, showing eharacteristic nodules .....	27

## LEGUMINOUS CROPS FOR GREEN MANURING.

### GREEN MANURING.

Green manuring, or the plowing under of green crops (figs. 1 and 2), is one of the oldest methods used to maintain or to increase the productivity of the soil. The effect of green manuring varies according



FIG. 1.—Field of cowpeas ready to plow under.

to the original character of the soil. In general, sandy or gravelly soils are made darker in color and become more retentive of moisture. Clayey soils are made more porous and friable, so that they are less likely to puddle or bake, and are less subject to washing. Loamy soils are less noticeably affected than others.

The most important object achieved by green manuring is the addition of humus to the soil. Other things being equal, the best green-manure crop is that which furnishes the largest amount of material which will readily decay in the soil and thus form humus. There are, however, additional ways in which such a crop may be beneficial. Deep-rooted plants are decidedly preferable to shallow-rooted

ones because they penetrate into the subsoil. In this way air and water find entrance, especially after the roots decay. Thus in a way every deep-rooted plant is a subsoiler. It is also supposed that such plants, especially when plowed under, tend to enrich the surface soil with potash and phosphorus from the subsoil, thus bringing these substances within the reach of shallow-rooted plants.

Leguminous plants are more valuable for green manuring than others because they not only provide humus but also have the ability to use the nitrogen of the air, which upon decaying they add to the soil. For this reason green-manure crops should always be legumes if such are adapted to the particular locality where needed and can be sown at the time desired.

### THE USE OF GREEN MANURES.

Green manuring as a definite farm practice can be recommended only under certain conditions. It is profitable in upbuilding poor



FIG. 2.—Plowing under a crop of cowpeas.

soils and in improving the physical condition of sandy, clayey, and adobe soils. In orchards green manures may, as a rule, be used very advantageously, as they do not interfere with the fruit crops.

Green manuring can not be recommended on good soils, except at long intervals when there is reason to believe that there is need either of more humus or more nitrogen. Where red clover or alfalfa can be used in rotation the need of a special green-manure crop is seldom felt.

The reason lies in the fact that about one-third of the weight of the clover plant and nearly one-half of that of alfalfa is in the root, so that these plants virtually produce a green-manure crop under the ground in addition to the regular crop of hay. Sweet clover is another plant of this class and of wide adaptation as to soil and climate, but unfortunately the hay is not readily eaten by cattle, so that it is used in limited sections only.

A serious objection to a green-manure crop lies in the fact that it must ordinarily take the place of a regular crop, so that the income from the land is lost for the season. The value of the practice in any particular case must be measured by the results secured in the subsequent crop. Frequently it will happen that as good or nearly as good results can be obtained by the use of commercial fertilizers; in such cases it is often best to use them, thus retaining the use of the land for the season. Sooner or later, however, the humus of the soil becomes depleted and must be replaced. Where clover or some similar large-rooted crop can not be used in rotation, recourse must be had either to green manuring or to the application of barnyard manure.

The use of green manures in semiarid regions is as a rule impracticable, as with insufficient moisture vegetable matter decays very slowly. The soil is thus filled with air spaces and loses much more water by evaporation.

### THE PRINCIPAL LEGUMINOUS CROPS.

There are in the United States 15 leguminous field crops that are more or less extensively grown. In the approximate order of their importance they are as follows: Red clover, alfalfa, cowpeas, alsike clover, crimson clover, white clover, Canada peas, soy beans, peanuts, vetch, velvet beans, Japan clover, and bur clover. A few more are cultivated to a less extent, as sweet clover, beggarweed, grass peas, fenugreek, and horse beans. Many others have been tested in an experimental way, but as yet are not grown as crops.

From an agricultural point of view legumes may be classified into three groups: (1) *Summer annuals*, including cowpeas, soy beans, peanuts, beans, velvet beans, and in the North common vetch and Canada peas; (2) *Winter annuals*, comprising crimson clover, bur clover, hairy vetch, and in the South common vetch and Canada peas; (3) *Biennials or perennials*, embracing red clover, white clover, alsike clover, alfalfa, and sweet clover.

Each of these crops can be grown advantageously only in a more or less definitely limited region. For the particular purpose in view, it rarely happens that a choice of two or more equally valuable legumes is offered. Usually one is so much superior to any other



available that substitution is practically out of the question. In a few cases, however, the use of one legume in place of another is practicable. Thus cowpeas and soy beans are agriculturally much alike and are adapted to nearly the same regions. In a like manner crimson clover, bur clover, and the vetches over a large area may be used one in place of another. In some sections the culture of red clover is no longer profitable, principally owing to diseases. Alsike clover has been used to some extent as a substitute, but the yield is ordinarily much less. There is also an increasing use of alfalfa in place of red clover, but with alfalfa the best practice is to keep the fields in this crop three years or longer.

### **HOW LEGUMES GET NITROGEN FROM THE AIR.**

It was known even in ancient times that much larger crops of various kinds could be produced on land that had been in clover or lupines the previous season.

In modern agriculture the value of legumes is quite generally appreciated, as seen in the common practice of growing clover or some other legume in rotation at frequent intervals. The reason why legumes have a beneficial effect was discovered by Hellriegel and Wilfarth in 1886, though many accurate experiments had long before proved the fact.

An examination of the roots of leguminous plants will reveal on many of them nodules or tubercles; sometimes very few, sometimes very many. (See figs. 4, 7, and 14.) These vary in size and shape according to the kind of plant. Thus, on red clover (see fig. 4) they are more or less round, and quite small; on the cowpea they are also round and nearly smooth, but much larger; on the velvet bean they may even reach the size of a pigeon egg; on the vetches they are irregular, both in shape and size. The differences in the tubercles are such that in many cases it is possible to determine the plant to which the root belongs.

Hellriegel and others have proved beyond any question that when leguminous plants have these tubercles on the roots they can make use of the free nitrogen of the air; when they do not have these tubercles they are powerless to do this, but must obtain their supply of nitrogen from the soil in the same manner as most other plants. It has further been proved that these tubercles are caused by a certain kind of bacteria, and that it is really by these bacteria that the nitrogen of the air is absorbed so that it can be used by the clover or by other legumes. There is thus a peculiar interrelation established between the leguminous plant and the bacteria. The latter obtain their principal nourishment from the legume, while in turn they provide nitrogen from the air which can be used by the host plant.

## INOCULATION.

Nearly every legume has its own particular strain of nodule bacteria. For example, that of the clover is different from that of alfalfa, and that of the cowpea distinct from that of the soy bean. In planting a leguminous crop for the first time it will therefore often happen that no tubercles will form on the roots, because the proper kind of bacteria is not present in the soil. These may be supplied by scattering soil from a field where the crop in question has been recently grown, or by using an artificial culture of the proper bacteria. After the field is once thoroughly inoculated there is rarely any difficulty afterwards in getting an abundant supply of root tubercles.

The same strain of bacteria will often inoculate different closely related legumes. Thus alfalfa, bur clover, and sweet clover are tubercled by the same strain; a different strain inoculates most kinds of vetches, as well as the field and garden peas; still another strain is apparently used by red clover, white clover, and alsike clover in common.

There is a marked variation among different legumes, both in the extent to which they are naturally tubercled and in the ease with which different ones may be artificially inoculated. Natural inoculation presupposes the existence of the proper germ in the soil, and this is nearly always present over areas where a particular legume has been generally grown. Thus red clover is practically always naturally inoculated in the northeastern quarter of the United States and cowpeas in the southeastern. Alfalfa is naturally tubercled as a rule in the West, while in the East artificial inoculation is usually necessary.

Artificial inoculation is usually accomplished with ease as regards cowpeas, red clover, vetches, field peas, and most other legumes. Soy beans, however, frequently give negative results. Sweet clover is much more readily inoculated than alfalfa, though both use the same strain of bacteria.

In some cases the tubercle germs occur in sufficient abundance on the seeds to provide inoculation. This occurs more particularly on seeds that are tramped out by oxen or which otherwise become covered with dust from the field. An interesting illustration of this occurred in 1906 in the case of guar, an East Indian legume. Neither this plant nor any closely related species had previously been grown in this country. Nevertheless, at Chillicothe, Tex., the plants were abundantly tubercled.

## SOURCES OF SOIL NITROGEN.

Nitrogen, as purchased in commercial fertilizers, such as nitrate of soda, guano, tankage, and dried blood, is the most expensive manurial substance a farmer has to buy. Its cost in these various forms ranges from 15 to 20 cents a pound. To a very large extent, at least, the purchase of the costly nitrogenous fertilizers can be avoided by the growing of green-manure crops, especially legumes.

There are two principal ways in which nitrogen is naturally added to the soil. The first and much more important way is by means of legumes. This takes place only when the roots of the leguminous plant bear bacterial nodules or tubercles. The amount of nitrogen that any particular legume can add is directly proportional to the number and size of the tubercles on its roots. Little is known regarding the relative abilities of different legumes to fix atmospheric nitrogen, though they differ widely. It has sometimes been assumed that those are most efficient whose herbage is richest in this substance. This is at least questionable, as these same species may be able to utilize more of the soil nitrogen than others.

The second way in which nitrogen is added to the soil is through the activity of certain soil bacteria. These, especially if provided with decaying vegetable or animal matter, are able to use the nitrogen of the air, forming nitrogen compounds. The amount of the nitrogen thus fixed depends on a number of factors. A supply of decaying material must be available as food for the bacteria, the soil must be well aerated and must not be sour, and there must be lime or other substance in the soil with which the nitrogen can be combined. With these conditions fulfilled the bacteria are most active when the soil is warm—that is, in summer. It is now believed that the principal benefit achieved by summer fallowing is the increase in the amount of nitrogen by soil bacteria. It may here be pointed out that in experiments green-manure crops have yielded the best results when turned under shallow. This result is perhaps due to the fact that the best conditions are thus provided for the activity of the soil bacteria.

Two general methods of determining the amount of nitrogen added to the soil by a leguminous crop have been employed. The first is by analyzing the soil before the crop is grown and again afterward. The other method is to determine the nitrogen content of plants with tubercles as compared with those that have no tubercles. The difference will show approximately the amount of nitrogen gathered from the air. The error, if any, in the latter method will be an underestimate, as there is reason to believe that some nitrogen passes from the root tubercles to the soil before the plant is mature.

At the Illinois Agricultural Experiment Station it was found that cowpea plants with tubercles on the roots were not only much larger,

but that they also were much richer in nitrogen. Those with tubercles yielded 3.96 per cent of nitrogen, while those without tubercles had but 2.22 per cent of nitrogen.

At the Michigan Agricultural Experiment Station it was found that soy beans with tubercles on the roots yielded 113.55 pounds of nitrogen per acre, while those without tubercles yielded but 75.98 pounds. Cowpeas yielded, respectively, 139.21 and 118.45 pounds. Thus the soy bean tubercles increased the amount of nitrogen by 37.57 pounds per acre, or nearly 50 per cent, while the cowpea increase was but 20.76 pounds per acre, or a little more than 20 per cent.

### LOSS OF SOIL NITROGEN.

It is important to know that under certain conditions nitrogen may escape from the soil as a gas. This result is brought about principally by certain organisms, called denitrifying bacteria, that break up nitrogen compounds and permit the nitrogen to escape, usually in the form of ammonia. Little is yet known of this process, but it is believed to occur under various different conditions. There are probably different bacteria which under different conditions cause these losses. It is known, however, that large loss is likely to occur when there is present abundant decaying matter, high temperature, and lack of air. Such losses occur particularly in rich water-logged lands and in manure heaps. For these reasons it is not good practice to endeavor to obtain a large store of nitrogen in the soil beyond the needs of the crops. For the same reason green-manure crops should not be used on lands that are decidedly wet.

### COMPOSITION OF GREEN-MANURE CROPS.

The essential fertilizing substances added to the soil as manures are nitrogen, phosphorus, and potash. The accompanying table gives the amount of these substances in both the tops and roots of several legumes, as shown by a number of analyses of each.

It has been found that all plants vary widely in the relative amount of these materials they contain. The same plant varies when grown on different soils or in different seasons on the same soil. The cause for the variation in nitrogen has been fully explained. The reason for the variation as regards the other substances which are obtained wholly from the soil are obscure. In the accompanying table it will be noted that the variation in legumes as regards phosphorus and potash is nearly as great in any one legume as it is between different legumes. It has been suggested by several writers that certain green-manure crops by feeding heavily on phosphorus and potash make these substances more available to subsequent crops. It is very

doubtful whether this is true, but if it is there is little apparent advantage of any one legume over another in this respect.

*Fertilizing materials in 100 pounds of dry substance.*

[Compiled from various sources.]

Plant and part.	Nitrogen.	Phosphoric acid.	Potash.	Plant and part.	Nitrogen.	Phosphoric acid.	Potash.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>		<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
Red clover:				Cowpea—Cont'd.			
Tops .....	2.56	0.72	1.40	Tops .....	2.09	.56	3.04
Tops .....	2.07	.38	2.20	Roots .....	1.19	.67	1.94
Tops .....	1.97	.56	1.86	Roots .....	.68	.64	1.16
Tops .....	2.81	.65	3.10	Roots .....	1.46	.16	.77
Roots .....	2.74	.84	.82	Roots .....	1.40	.73	.76
Alfalfa:				Soy bean:			
Tops .....	2.42	.58	1.42	Tops .....	2.06	.80	1.20
Tops .....	2.30	.53	1.46	Tops .....	2.32	.67	1.08
Tops .....	2.19	.51	1.68	Tops .....	2.97	.55	1.98
Roots .....	2.04	.43	.48	Tops .....	2.60	.65	2.23
Crimson clover:				Tops .....	1.53	.57	1.76
Tops .....	2.38	1.10	1.56	Tops .....	2.01	.65	2.17
Tops .....	2.05	.40	1.31	Tops .....	1.75	.40	1.32
Tops .....	1.95	.36	1.17	Roots .....	.81	.36	.90
Roots .....	1.50	.47	1.02	Roots .....	1.22	.32	.24
Cowpea:				Roots .....	1.11	.35	.87
Tops .....	2.32	.51	2.92	Velvet bean	2.51	.53	3.84
Tops .....	1.81	.65	1.29	Common vetch:			
Tops .....	1.59	.30	1.53	Tops .....	3.53	.74	2.56
Tops .....	1.95	.52	1.47	Tops .....	3.18	.77	3.50
Tops .....	1.75	.45	1.27	Tops .....	2.27	.62	1.97
Tops .....	2.23	.57	2.00	Roots .....	2.19	.79	1.18

## GREEN MANURING COMPARED WITH FEEDING.

Barnyard manure contains from 75 to 90 per cent of the total fertilizing substance in the feeds used. It is beyond question a better practice from all standpoints to feed a crop, whether leguminous or nonleguminous, and then distribute the manure over the land, than it is to plow under the whole crop. This practice utilizes the whole feed value of the crop. Further, it returns an important part of it to the soil in a highly available form for plant food. Unquestionably this is the very best farm practice in maintaining soil fertility. Were it possible on any farm to feed the entire product to live stock, returning the manure to the soil, the productivity of that farm would be maintained indefinitely. The only depletion that would occur would be the comparatively small amount of potash and phosphorus sold in the live-stock product. The loss of nitrogen would be more than maintained by the activity of the soil bacteria.

It is, of course, well known that other causes than the removal of plant food may reduce the productivity of the soil. Such causes as sour soil, the deleterious effect of one crop upon the succeeding one, and poor tillage may and often do result in poor crops. These causes are, however, largely within the control of the farmer and in no way affect the general statements above made.

The feeding of crops, taken as a whole, is necessarily limited by the total demand for live stock. The total number of live stock required to supply the market demands can furnish but a small proportion of

the manure needed. On this account the practical use of barnyard manure is naturally limited to regions where animal husbandry is prominent. Where stock raising is but little developed recourse must be had to other fertilizers. It is primarily in such regions that the use of green manures is necessitated.

### ORCHARD COVER CROPS.

The term "cover crops" was originally used to include crops grown for various diverse purposes, such as to prevent soil washing, to hold drifting snow, for keeping the soil warm in winter, and to hasten the ripening of wood. As these crops were used largely in orchards and as they were often legumes, so that they might serve also as green manures, the term "cover crop" is frequently used to include crops grown in orchards primarily for green manure.

The growing of leguminous crops in orchards is generally considered excellent practice, except in dry regions where irrigation is impracticable.

In the citrus orchards of southern California a number of different legumes are used as winter cover crops; among them Canada peas, common vetch, hairy vetch, and fenugreek. Besides these, many others have been tried in an experimental way, such as horse beans, scarlet vetch, black-purple vetch, lupines, sweet clover, and berseem. The two first mentioned are most used at present, and the general opinion is that the practice is decidedly profitable. There is, however, a lack of accurate data on this point. Some orange growers are also using cowpeas as a summer cover crop.

In Delaware and other States of the Atlantic seaboard, crimson clover is the most common legume used as a cover crop. To a less extent common vetch and hairy vetch are employed.

At the Ohio Agricultural Experiment Station it was found that apple trees grew more rapidly and yielded larger crops when the orchard was kept in grass. After each mowing the straw was used as a mulch about the trees. Where the trees were cultivated in a circle of 3 or 4 feet about the base, the results were distinctly inferior. Clean summer culture with a winter cover crop gave results intermediate between the other two.

It is probable that the best results in different portions of the country will be obtained by different methods. There is much need of determining accurately the results of different treatments as shown both by the growth of the trees and the crop produced.

## CROPS TO FOLLOW GREEN MANURES.

The plowing under of large quantities of green herbage, as illustrated in figure 2, p. 6, especially when this is done during the summer, often brings about the formation of considerable acid, or, in other words, makes the soil sour. This condition may be corrected by the use of lime, which should be applied at the rate of a ton to a ton and a half to the acre. Some farmers claim to get much better results by applying the lime before plowing under the crop. In any case, it is advisable to let the green manure after being plowed under decay a month or more before planting the succeeding crop.

The full results of a green manure are obtained only after it is completely decayed and changed into a soluble form. This requires considerable time, so that the beneficial results are often shown for two or more seasons.

Generally speaking, cultivated crops are the best to follow green manures. The tillage of such crops hastens the decay of the vegetable matter and, by aerating the soil, favors additional nitrogen fixation by the soil bacteria. Corn, cotton, potatoes, and tobacco, on most soils, derive great benefit when following green manures. Rye and oats are likewise good crops to use in this way. Wheat and barley give varying results, often very favorable, but not infrequently there is no increase or even a loss. This is especially true the first season following a green-manure crop.

## THE CHOICE OF A GREEN-MANURE CROP.

Whenever a green-manure crop is to be used, preference should be given to a legume if it is available, because such a crop will add materially to the nitrogen content of the soil. Where there is a choice between two or more legumes, the question arises as to which is to be preferred. Among the important points that determine the value of a leguminous crop are (1) its value as forage, both in quantity and quality, either as hay or pasture; (2) its ability to supply additional nitrogen. Other points that deserve consideration are the cost of the seed, the ease of plowing under the crop, the deep-rootedness of the plants, and their ability to choke out weeds. On lands of fair quality the largest profit is usually obtained by using the crop as fodder. This may be done by harvesting it for hay, leaving only the stubble to be added to the soil, or by pasturing the crop, by which means the most of it is returned to enrich the land.

Where the whole crop is plowed under, the effect on the subsequent crops is determined mainly by three factors, namely, the amount of humus formed, which is directly measured by the tonnage of the crop; the physical changes brought about in the soil, and the quantity of



nitrogen taken from the air and added to the soil. It is generally believed that the addition of nitrogen is the most important of these factors. While different legumes are known to vary in their respective abilities to absorb atmospheric nitrogen, there is much yet to be learned on the subject. If the benefit of different legumes is proportional to the amount of nitrogen each adds to the soil, then their relative values can be determined in advance. Thus far the value of different green manures has been determined wholly or mainly by the influence they have on the succeeding crop or crops.

## THE PRINCIPAL GREEN-MANURE CROPS.

### RED CLOVER.

Red clover (figs. 3 and 4) is the most common legume used in rotations in the Northern States. It is usually grown with timothy, following wheat or other small grains. As a general rule the timothy seed is sown in the fall with the grain, and the clover is sown the following spring. While the beneficial effect of plowing under red clover or red clover sod is well known, there has been but little work done at the agricultural experiment stations to determine accurately the amount of benefit thus secured. Results obtained at the Illinois Agricultural Experiment Station gave an average yield of  $35\frac{1}{10}$  bushels of corn where this crop was grown year after year on the same land. In rotations, the average yield was  $55\frac{1}{10}$  bushels for the first crop after clover and  $48\frac{3}{8}$  bushels for the second crop after clover.

Some exceedingly interesting results on red clover as a green manure, secured by the Central Experimental Farm, Ottawa, Canada, have recently been published.

In one of these experiments four plats were planted to spring grains with red clover and four to the same grains without red clover. After the grain crops were harvested the clover was allowed to grow



FIG. 3.—Red clover.



on the four plats, and having attained a good growth was plowed under in October. The remaining four plats without red clover were plowed at the same time. The following spring all eight plats were seeded to oats. Those that had been in clover yielded an average of  $49\frac{2}{10}$  bushels to the acre, against  $38\frac{4}{5}$  bushels for the plats that had no clover. All four of the plats that had been in clover showed an increase, the greatest being  $19\frac{2}{5}$  bushels and the least  $7\frac{1}{5}$  bushels. Without additional fertilizers the same plats were seeded the following year to barley. Those that had been in clover yielded an average

of  $37\frac{3}{5}$  bushels to the acre, while the others yielded but 29 bushels. This experiment furnishes a clear demonstration that the good effect of the clover lasts more than one season.

In another experiment oats were grown on four plats, following, respectively, brome-grass, mixed grass without clover, mixed grass with clover, and clover alone. The respective yields were  $33\frac{1}{10}$ ,  $36\frac{3}{10}$ ,  $46\frac{1}{10}$ , and  $43\frac{1}{2}$  bushels. The average of the two plats where no clover had been used was  $34\frac{1}{2}$  bushels, while that of the two where clover had been used averaged  $44\frac{1}{2}$  bushels. The benefit derived

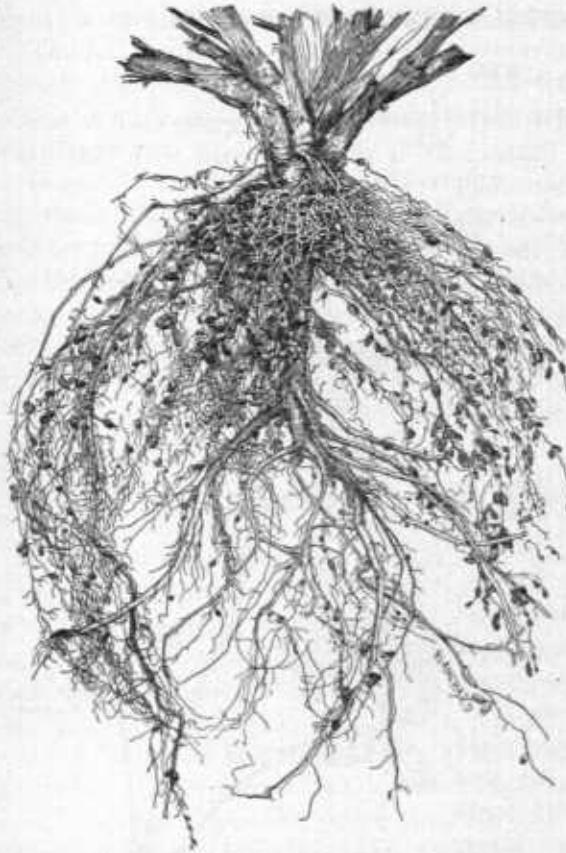


FIG. 4.—Roots of red clover showing nodules.

from the red clover therefore amounted to 10 bushels per acre more than was derived from the grasses.

Other experiments conducted in this same series showed very marked favorable results both to crops of fodder corn and potatoes following clover. In the case of corn the increase amounted to 40 per cent and in the case of potatoes to 28 per cent.

## COWPEAS.

The cowpea (fig. 5) is used more than any other crop as a soil renovator in the South. Its use is rapidly increasing, but is yet far from general. During the past few years the high price of the seed has tended to discourage more extensive growing. Recent progress in the harvesting of cowpea seed by machinery will doubtless materially reduce its cost. The seed is at present almost entirely picked by hand.

The cowpea is characterized by remarkable ability to grow in poor soils and to cover the ground so densely as to choke out most weeds. It usually bears an abundance of tubercles on its roots, whether the soil has been inoculated or not, although in new localities where the cowpea has not been previously grown the tubercles may be absent. In such cases inoculation is necessary, for it must always be remembered that it is through the tubercles on the roots that the beneficial effects of the cowpea or other legume largely depend.



FIG. 5.—Cowpea.

Cowpeas are very commonly planted between rows of corn at the time of the last cultivation, or they are broadcasted upon the stubble of small grains. Cowpeas, however, like other crops, respond markedly to cultivation and there is a growing tendency to plant them upon well prepared soil. This practice results in a great increase of the crop, whether grown for hay or for seed. (See fig. 1, p. 5.)

More numerous experiments have been conducted in this country to determine the effects of cowpeas used as a green manure than have been devoted to all other leguminous crops combined. Almost without exception these experiments have indicated a very beneficial

effect upon the succeeding crop. The benefit often lasts two or three years. These good results follow on practically all succeeding crops, whether cotton, corn, sorghum, or small grains. Except on the poorest soils careful experiments show that it is decidedly more profitable to use the cowpea crop as hay or pasture and then plow under the stubble than it is to plow under the whole crop. While plowing under the whole crop produces as a rule a greater effect, it is not enough greater to equal the value of the cowpea crop as feed.

A few of the striking results obtained at southern experiment stations are here given. At the Arkansas Agricultural Experiment Station the effect of cowpeas upon the succeeding wheat crops was studied for a period of four years. The land on which the experiments were conducted had all been in wheat in 1898. This was divided into equal plats, and on some of these plats Whippoorwill cowpeas were planted, while others were left bare. The average yield on two plats where wheat was grown continuously and no cowpeas were used was  $10\frac{1}{10}$  bushels. On two other plats where a crop of cowpeas was plowed under in the autumn of 1898 the average yield was increased to  $14\frac{1}{10}$  bushels for the four years, and the beneficial effect of the cowpeas plowed under in 1898 persisted, with a gradual diminution, through the four succeeding years. Where only cowpea stubble was plowed under in the autumn of 1898 the average yield for the four years was  $12\frac{3}{8}$  bushels, and a slight beneficial effect was still observable in the fourth year. On two other plats cowpeas were planted each season after the wheat was harvested and the stubble plowed under. The average yield of wheat on these plats was  $14\frac{2}{8}$  bushels. Furthermore, the yield on these last two plats increased year after year until the last year of the experiment, one of them yielding  $16\frac{9}{10}$  bushels and the other  $17\frac{3}{8}$  bushels, the highest yields reported in the entire experiment. In comparison with these experiments with cowpeas other plats were also treated with commercial fertilizers. The effect of adding 200 pounds of nitrate of soda in the autumn of 1898 raised the average yield of wheat to nearly 11 bushels per acre and the entire additional effect was obtained during the season following the application. Where 800 pounds of complete fertilizer were used in the autumn of 1898 the average yield of wheat was increased to 13 bushels per acre, the most marked effects being during the first and second years. On the soil where these experiments were conducted there is thus a clear advantage in favor of the cowpeas, even if the value of the cowpea crop in itself be ignored.

Among the numerous experiments with cowpeas conducted by the Alabama Agricultural Experiment Station were a number to determine the effect of plowing under cowpea vines on a succeeding crop of cotton. The yield of seed cotton thus produced in 1899 was 1,533

pounds, as against 837 pounds on an adjoining plat that had been in cotton the previous season, thus giving a clear gain of 696 pounds of seed cotton, valued at \$17.40.

In another experiment sorghum yielded 5.66 tons of hay following cowpea stubble, 5.72 tons following cowpea vines plowed under, and only 3.65 tons following a previous crop of sorghum. The cowpeas here in each case gave a clear increase of more than two tons per acre.

In a third experiment oats following cowpea vines plowed under yielded  $22\frac{4}{5}$  bushels per acre, while following German millet plowed under they yielded only  $12\frac{2}{5}$  bushels. In another similar experiment oats following cowpea stubble yielded  $34\frac{2}{5}$  bushels and following cowpea vines plowed under  $28\frac{4}{5}$  bushels, while following German millet the yield was  $9\frac{9}{10}$  bushels. These last experiments indicate that the effect of a leguminous green-manure crop is probably due largely to the nitrogen which it adds to the soil, as it may be assumed that the amount of humus supplied by the millet was approximately equal to that added by the cowpeas. It is possible, however, that the millet may have tended to reduce the normal yield instead of increasing it.



FIG. 6.—Soy bean.

#### SOY BEANS.

Soy beans (fig. 6) are adapted to a much wider range of climate than cowpeas, being grown successfully even in Ontario and Massachusetts. As a forage crop soy beans have some points of superiority over cowpeas, the hay being somewhat easier to cure and richer in

protein. The seed is also cheaper than that of cowpeas, usually costing only two-thirds as much. This is principally due to the fact that the seed can readily be harvested by machinery. It also has an advantage in that the seeds are but little affected by weevils. On these accounts soy beans are preferred by an increasing number of farmers in the South. Soy beans, however, are not able to compete with weeds as successfully as cowpeas, and on this account the best results are obtained by planting in rows, so that they may be cultivated. There is considerable difficulty experienced at first in obtaining tubercles on the roots of soy beans, but when once these have appeared in a particular piece of ground there is no further trouble.

Apparently, soy beans have a greater power than cowpeas to absorb atmospheric nitrogen through their roots (fig. 7).

In an investigation conducted at the Michigan Agricultural Experiment Station it was found that inoculated soy beans were enabled to add per acre 37.57 pounds of nitrogen provided from the air. (See p. 11.) At the Arkansas Agricultural Experiment Station soy beans used as green manure gave nearly as good results as cowpeas, as determined by subsequent crops of



FIG. 7.—Roots of soy bean, showing nodules.

wheat, oats, cotton, and corn. With cotton, the soy bean vines produced a larger yield of cotton than cowpea vines, but the cowpea stubble gave a larger yield than the soy bean stubble. With corn, cowpea stubble and soy bean stubble yielded the same results, while soy bean vines gave better results than the cowpea vines. With oats, the results were slightly in favor of the cowpeas. It is not improbable that the variation in results may be largely due to variation in the

amounts of atmospheric nitrogen added by the legumes to the different plats. Those that were most heavily tubercled would add the most nitrogen.

#### VELVET BEANS.

Velvet beans (fig. 8) have been tested in comparison with cowpeas at the Arkansas and Alabama agricultural experiment stations. The velvet bean is somewhat objectionable on account of the very viny habit of the plant, which renders it difficult to plow under. In orchards velvet beans have been found objectionable on account of their tendency to climb the trees. At the Arkansas Agricultural Experiment Station velvet beans gave better results on a subsequent crop of cotton than either soy beans or cowpeas, the velvet bean plat

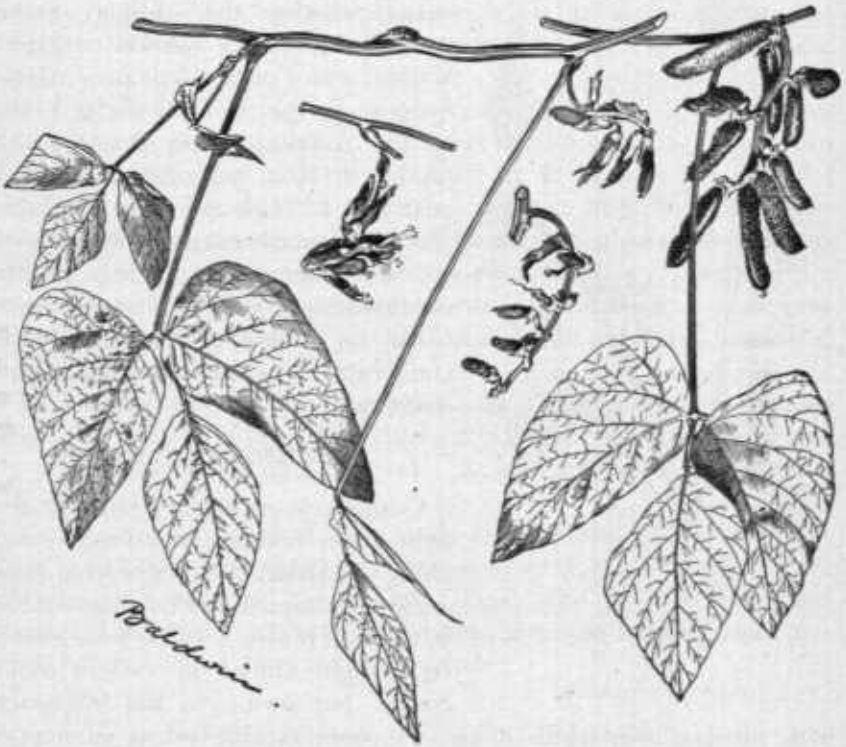


FIG. 8.—Velvet bean, showing leaves, flowers, and young pods.

yielding 1,550 pounds of seed cotton, against 1,448 pounds for the soy beans and 1,335 pounds for the cowpeas. With wheat, velvet bean stubble gave better results than either cowpea stubble or soy bean stubble, though the difference was very slight. It is noteworthy also that velvet bean stubble gave much better results on the succeeding crop of wheat than where the whole crop of velvet bean vines was plowed under, and the same was true in regard to both cowpeas



and soy beans. In all cases, however, there was a marked increase of crop, due to the influence of the legumes.

At the Alabama Agricultural Experiment Station the following yields of sorghum hay were obtained: After fallow, 3,792 pounds per acre; after cowpeas plowed under, 7,008 pounds; after velvet beans plowed under, 7,064 pounds. Here the legumes nearly doubled the yield of the sorghum hay, the velvet beans being slightly better than the cowpeas. In a similar experiment where only the stubble was plowed under, the velvet beans in two cases showed a slight supe-

riority over the cowpeas. Where corn was used to determine the effect of the legume, cowpeas gave slightly better results than similar plats with velvet beans, whether the stubble or the whole vines were plowed under. Where cotton was used as a measuring crop, the results were in favor of the cowpeas. The cowpea plat produced 1,533 pounds, the velvet bean plat 1,373 pounds, and the check plat 837 pounds, respectively, of seed cotton. Comparison of all the results obtained showed that there is practically no difference as regards fertilizing value between velvet beans and cowpeas.

#### CRIMSON CLOVER.

Crimson clover (fig. 9) is much grown as a green manure and forage crop along the Atlantic seaboard from New Jersey southward and to a less extent in the Gulf States. It has been grown to a slight extent in various other States, but owing to the frequency

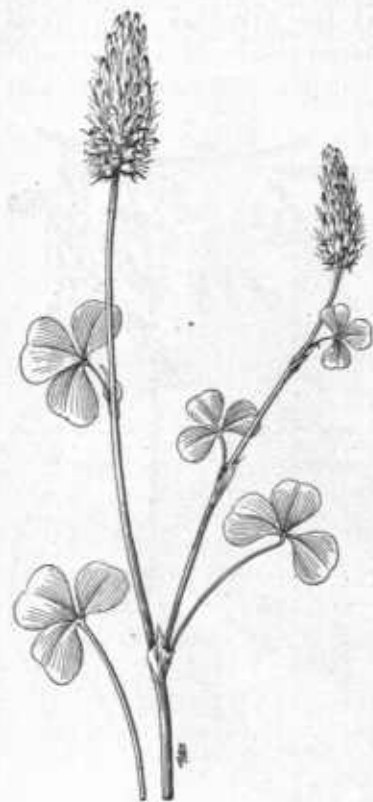


FIG. 9.—Crimson clover.

with which it winterkills it has not been established as an important crop. It is most largely grown in the Middle Atlantic States, and its use has greatly increased in late years.

Crimson clover gives the best results when sown in late summer, preferably from July 15 to September 1. It is most commonly planted in corn or following a small grain crop. In the latter case the land should be plowed and put in good condition before seeding. Considerable difficulty is often experienced in obtaining a stand of crimson clover. Indeed, it is a common saying that it must be sown

between showers in order to be assured of a stand. It is important always to use fresh seed, as the germinating power deteriorates rapidly. Ordinarily 12 to 15 pounds per acre is used, but good results have been obtained with smaller quantities. In some cases the failure to obtain a stand has been attributed to the lack of inoculation. In any event it is always desirable to inoculate the seed or the soil before planting on land for the first time. Even if a stand is only obtained two times out of three crimson clover is still a very profitable crop to grow.

A number of careful experiments with crimson clover have been conducted both by the Delaware and Maryland agricultural experiment stations. At the Maryland Agricultural Experiment Station it was found that potatoes following crimson clover plowed under yielded  $72\frac{3}{10}$  bushels per acre, while on an adjoining plat where no crimson clover had been sown the yield was  $52\frac{1}{2}$  bushels. On the same plats the following year the yields were, respectively,  $102\frac{1}{2}$  bushels and  $67\frac{1}{2}$  bushels—an increase of 27 bushels per acre, or more than 45 per cent, due to the effect of the crimson clover. In a similar experiment with corn a yield of 46 bushels per acre was obtained following crimson clover, as against  $39\frac{3}{10}$  bushels where no clover had been sown. At the Delaware Agricultural Experiment Station sweet potatoes yielded an increase of about 18 bushels per acre, due to the effect of crimson clover, a gain equal to that produced on adjoining plats by the addition of 160 pounds of nitrate of soda.

In addition to its value as a green manure, crimson clover is also important as a cover crop, tending to prevent the leaching and washing of soils, especially on hilly land. As a cover crop it is much employed in orchards.

For the improvement of poor lands in the Middle Atlantic region there is no better plan than to use crimson clover as a winter crop and cowpeas as a summer crop. One farmer who adopted this plan succeeded in raising 35 bushels of wheat per acre on land that had never before yielded more than 16 bushels.



**SWEET CLOVER.**

Sweet clover (fig. 10) is a biennial plant, somewhat weedy in character, which grows readily on almost all soils. It produces an enormous root, and the tops often grow to a height of 4 or 5 feet. Owing to the bitter character of the herbage it is not much liked by stock, which have to learn to eat it. In a few sections of the country it is grown as a hay crop. As a crop, sweet clover is most largely grown in Alabama and Mississippi, where it is utilized both for hay and for its improvement of the soil. It is considered at least equal to red clover for the latter purpose.



FIG. 10.—Sweet clover.

Owing to the ability of sweet clover to grow in the poorest of soils, it will probably be found of high value in increasing their fertility. The seed should be planted very early in the spring, using about three-fourths of a bushel of the seed in the pod, the common form in which it is found on the market. The greatest benefit will be found in plowing it under the second season, before it blooms.

In an experiment conducted at a German agricultural experiment station sweet clover was sown in May with rye, seeding at the rate of 21 pounds of hulled seed per acre. The following summer the sweet clover was plowed under and followed with oats. The yield was 1,099 pounds per acre on plats where no sweet clover had been sown and 1,645 pounds per acre where sweet clover had been used.

**CANADA PEAS.**

Canada peas (fig. 11) are grown mainly in the northernmost States and in Canada. As a winter green-manure crop in orchards they have been used considerably of late years in California. Very few accurate experiments have been conducted to determine the effect of Canada peas upon succeeding crops. In one such experiment conducted at the Ontario Agricultural College wheat was grown on three different plats

on which peas, rape, and buckwheat, respectively, had been plowed under. The yield of wheat following Canada peas was  $36\frac{1}{10}$  bushels; following rape,  $30\frac{2}{3}$  bushels; following buckwheat,  $26\frac{2}{3}$  bushels. There is here a clear gain shown in favor of the Canada peas. The impression prevails among farmers in the Canada pea belt of Michigan that oats following Canada peas yield an increase of from 5 to 10 bushels per acre, but there are no accurate experiments to substantiate this. At the Maine Agricultural Experiment Station oats were sown on some plats following Canada peas and on others following barley. On three out of four plats the yield of oats was larger following barley than following the peas, and the total of all the plats was much in favor of those that had been in barley the previous year. No mention is made as to whether the peas were tubercled or not.

In a series of rotation tests at the South Dakota Agricultural Experiment Station, extending over seven years, the effect of Canada peas on the wheat was to increase slightly the yield of straw without at all increasing the quantity of grain. Practically identical results were obtained on four different plats where peas

preceded wheat. The largest increase of straw was obtained where the peas had been pastured off by hogs. No benefit was observed on one plat where the whole pea crop was plowed under. No notes are published as to whether the peas were tubercled or not.

At the present time Canada peas are perhaps more used than any other legume in the citrus orchards in California. The effect is very satisfactory so far as improving the tilth of the soil and its ability to



FIG. 11.—Canada pea.

retain water are concerned. There are no accurate data available, however, as to the effect on the crop of fruit, but it is generally believed to be very favorable.

#### VETCHES.

Two vetches in particular are cultivated in the United States, the common vetch, or tares, and the hairy, or Russian, vetch. The former is much used as a winter crop for hay on the Pacific coast and in the

Southern States, being commonly sown with oats, rye, or wheat. It is also extensively grown in the citrus orchards of California as a winter green-manure crop. In the Northern States it is very likely to winterkill.

Hairy vetch (fig. 12) is in a general way like common vetch, but decidedly more resistant to cold. It will ordinarily survive the winter in most parts of the United States and in Canada. In fact it is more resistant to cold than any other annual legume grown. On this account it is particularly valuable in the North. In the Connecticut Valley it has received much favor as a winter green-manure and cover crop on tobacco lands,

Where the winter tempera-



FIG. 12.—Hairy vetch.

ture is not cool enough to prevent growing, as in California, it has been found that hairy vetch grows much more slowly in cool weather than the common vetch, and the latter is therefore preferred. Hairy vetch, however, grows very rapidly as the weather becomes warm.

Vetches are somewhat objectionable where small grains are used in rotation, as they become somewhat weedy in grain fields. Except for this, vetches are a very valuable crop and deserve much more extensive cultivation.

## TANGIER PEAS.

The Tangier pea (fig. 13) is a native of northern Africa and has been tested quite extensively in California during the past few years. The plant in a general way resembles the garden sweet pea. In comparison with other legumes in California, the Tangier pea has given the largest yields per acre. This pea is also characterized by its ability to form a very dense covering on the ground, so as to choke out weeds almost



FIG. 13.—Tangier pea.



FIG. 14.—Roots of Tangier pea, showing characteristic nodules.

perfectly. Indeed, no other legume tested on weedy land in California at all equals the Tangier pea in this respect. No experiments have yet been conducted to determine the effect of the Tangier pea when used as a green-manure crop, but from the numerous large tubercles found on the roots, as shown in figure 14, there is little doubt that it will prove exceedingly valuable in this respect. The hay is eaten readily by horses, and it is believed that the crop will become important.